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Exploration of Particle Size Engineering and Microencapsulation Technologies for Multifunctional Applications

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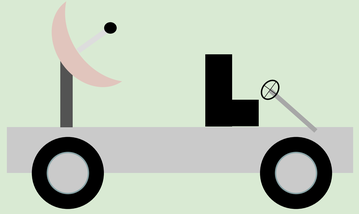
1 Introduction

Why Transition Metal-Aluminum-Boron (MAB) Phase Ceramics

- There is a need for high performance materials.
- Tires for exploratory rovers.
- External structures for landing vehicles.
- Ternary ceramics have proven to be a potential solution due to their hardness, mechanical properties, and oxidation resistance. [1]



2 Background

- **MAB phase ceramics are ternary ceramics**
  - M = Transition metal [1]
  - A = Aluminum [1]
  - B = Boron [1]
- **Molybdenum Aluminum Boride (MoAlB)**
  - Structure is made up of layers of covalent Mo-B and metallic bonded Al.
  - Mo and Al form weak metallic bonds that hold the layers together.
  - Properties include high strength, durability, oxidation resistance, and corrosion resistance. [2]
- **Iron Aluminum Boride (Fe_2AlB_2)**
  - Covalent Fe-B layers and metallic bonded Al.
  - Properties of Fe_2AlB_2 are similar to MoAlB.
  - The Curie temperature (T_c) is approximately 290 K.
  - Magnetic moments tend to vary in the range of 0.95–1.32 μB/Fe. [3, 4]

3 Manufacturing Process

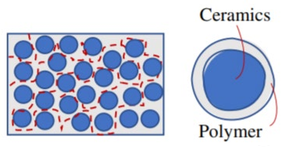
Images Courtesy of Mackenzie Short

Manufacture of Powders

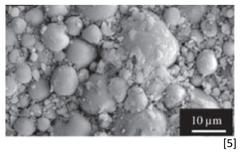
- Stoichiometric quantities of (Mo, Al, B or Fe, Al, B) were measured by using a digital scale.
- Powders were mixed for 20 minutes in a ball mill.
- After cold pressing, pellets were sintered for 2 h at 750 °C, then for 12 h at 1000 °C in Ar gas.
- Pellets were then crushed in a mill for 20 min.
- X-ray diffraction (XRD) analysis was performed on sieved powdered through 325 mesh (44 micron).
- XRD was performed to determine the composition of the powder.

4 Ceramic Encapsulation Background

- Solvent casting ceramic in polymer coats the particles. [5]
- At a concentration of over 70 wt. % ceramic, potential fracture paths form. [4]
- During ball milling, the polymer fractures, leaving microencapsulated particles. [4]
- The image below shows successful coating of a hydroxyapatite particle.



[5]



[5]

5 Microencapsulation Process

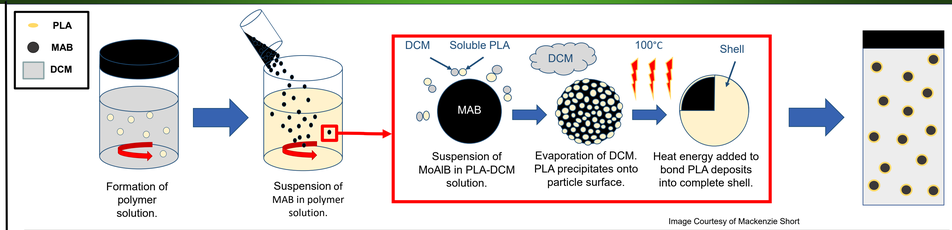


Image Courtesy of Mackenzie Short

- Add 10 wt. % polylactic acid (PLA) to dichloromethane (DCM) and mix for two hours.
- Place 90% wt. % MAB to PLA solution and mix for 10 min.
- Pour into mold and evaporate for 24 h in ambient air.
- Place in furnace at 100° C for an additional 24 h for drying.

6 Conclusions and Future Work

- The fabrication of MoAlB and Fe_2AlB_2 has been successful.
- Solvent casting has been verified to be a successful method for coating ceramic particles.
- Microencapsulation of MoAlB has been verified with scanning electron microscopy, thermogravimetric analysis, and differential scanning calorimetry.
- The University of North Dakota has microencapsulated bearing steel as well.
- Further work will be done on sintering and microencapsulating Fe_2AlB_2.
- Currently, we are exploring different types of sintering experiments with NASA Langley.

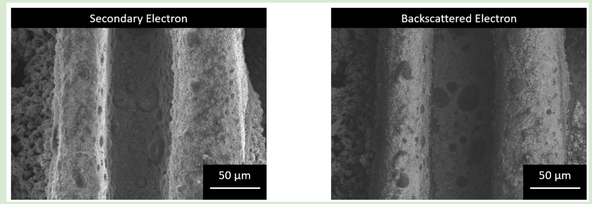


Image Courtesy of Daniel and Surojit

7 Acknowledgements

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[1] Kota, Sankalp, Eugenio Zapata-Solvas, Alexander Ly, Jun Lu, Omar Elkassabany, Amanda Huon, William E. Lee, Lars Hultman, Steve J. May, and Michel W. Barsoum. "Synthesis and Characterization of an Alumina Forming Nanolaminated Boride: Moalb." *Scientific Reports* 6, no. 1 (2016). https://doi.org/10.1038/srep26475.
[2] Zhang, Hongliang, Jun Young Kim, Ranran Su, Peter Richardson, Jianqi Xi, Erich Kisi, John O'Connor, Liqun Shi, and Izabela Szlufarska. "Defect Behavior and Radiation Tolerance of Mab Phases (MoAlB and FE2ALB2) with Comparison to Max Phases." *Acta Materialia* 196 (September 1, 2020): 505–15. https://doi.org/10.1016/j.actamat.2020.07.002.
[3] Liu, Jie, Shibo Li, Boxiang Yao, Shujun Hu, Jing Zhang, Wenbo Yu, and Yang Zhou. "Rapid Synthesis and Characterization of a Nanolaminated FE2ALB2 Compound." *Journal of Alloys and Compounds* 766 (2018): 488–97. https://doi.org/10.1016/j.jallcom.2018.06.352.
[4] Levin, E. M., B. A. Jensen, R. Barua, B. Lejeune, A. Howard, R. W. McCallum, M. J. Kramer, and L. H. Lewis. "Effects of Al Content and Annealing on the Phases Formation, Lattice Parameters, and Magnetization of *al*xfe2b2(x=1.0,1.1,1.2) Alloys." *Physical Review Materials* 2, no. 3 (2018). https://doi.org/10.1103/physrevmaterials.2.034403.
[5] Gupta, Surojit, Sabah Javaid, Maharshi Dey, Caleb Matzke, Erica Eades, and Yun Ji. "Exploration of Solvent Casting for Designing Engineered Microstructures for Biomedical and Functional Applications." *Journal of the American Ceramic Society* 105, no. 3 (2021): 1864–81. https://doi.org/10.1111/jace.18104.